NEST-SITE SELECTION OF WILSON'S PLOVERS (CHARADRIUS WILSONIA) IN SOUTH CAROLINA.

By

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Dedication:

I dedicate this thesis to my parents for always supporting me in my pursuit of birds.

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Nest-site selection of Wilson's Plovers (Charadrius wilsonia) in South Carolina

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Abstract:

Nest-site selection of Wilson's Plovers in South Carolina was studied at three spatial scales; landscape, habitat, and microhabitat. At the landscape scale a statewide survey was performed to locate adult plovers and the characteristics of islands and beaches used for nesting were determined remotely using ArcGIS. At the habitat and microhabitat level, North Island (Georgetown County) and Lighthouse Island (Charleston County) were surveyed for nests. Eight habitat categories were defined on the islands and the distribution of plover nests across these habitat categories was analyzed. At the microhabitat scale ten variables were measured at the nest and were compared against the same measurements taken at random locations. In 2006-2007 twenty-six sites were surveyed throughout the state and 369 adult Wilson's plovers were counted. Twenty-two sites were used in the landscape scale analyses. Percentage of beach at sites was positively correlated with the density of Wilson's Plovers. Sites with human development had a significantly lower density of Wilson's Plovers than sites lacking human development. At the habitat scale, in 2006 Wilson's Plovers used habitats differently than would be expected based on chance at North and Lighthouse Islands. In 2007 Wilson's Plovers only overused habitats at North Island. At the microhabitat level, distance to vegetation, distance to dead vegetation, distance to shells, slope, percent vegetation cover and percent shell cover were significantly correlated with the presence of Wilson's Plover nests.

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Introduction:

Shoreline beaches are critical to the reproductive success of several endangered and threatened bird species including the Piping Plover (*Charadrius melodus*), Snowy Plover (*Charadrius alexandrius*), and Least Tern (*Sterna antillarum*). Human development and recreational use of beaches decreases nesting and fledging success in beach-nesting birds such as Piping Plovers, Snowy Plovers, and Eurasian Oystercatchers (*Haematopus ostralegus*) (Flemming *et al.* 1988, Burger 1994, Rusticali *et al.* 1999, Ruhlen *et al.* 2003, Weston and Elgar 2007). As beaches become increasingly developed and human presence at these areas increases, many beach-nesting bird populations are decreasing.

Understanding where beach-nesting birds nest and the characteristics of nesting sites is important in conservation as habitat characteristics may be important to successful nesting. Nest environment (With and Webb 1993, Burger and Gochfeld 1986), nest success (Chase 2002) and adult well-being (Wolf and Walsberg 1996) often depend on nest location and associated habitat characteristics. Therefore, in many bird species, nesting locations are thought to be selected based on habitat characteristics (Lack 1933, Ryan and Renken 1987, Bergin 1992, Pampush and Anthony 1993, Conway *et al*. 2005).

Because habitat selection and the relative importance of different habitat characteristics might vary among spatial scales (Wiens *et al*. 1987), it is important to understand the habitat characteristics relevant to nest-site selection and nest success at a variety of spatial scales. Beach-nesting birds such as terns are thought to choose nesting sites in a hierarchical manner (Gochfeld 1977). Colony nesting birds must choose a colony site, a general habitat within that site, a nesting territory, and then finally the exact location of the nest within a territory (Gochfeld 1977). It is likely that most beach-nesting birds make this same series of choices and choose nesting sites on a landscape, habitat and microhabitat scale.

At the landscape scale, beach-nesting birds must choose among islands or beaches for nesting based on site characteristics which often influence nest and chick survival (Burger and Lesser 1980, Hanssen 1984, Lauro and Nol 1995, Rusticali *et al.* 1999, Knetter *et al*. 2002). For example, human development and human presence at beaches and islands influences nest and fledging success in beach-nesting birds (Flemming *et al.* 1988, Burger 1994, Rusticali *et al.* 1999, Ruhlen *et al.* 2003, Weston and Elgar 2007) and therefore might influence site selection. Availability of appropriate nesting areas and nesting substrate also may influence site choice. Pied (*Haematopus longirostris*) and Sooty Oystercatchers (*Haematopus fuliginosus*) showed preferences for beaches of differing substrates, with Pied Oystercatchers nesting more often on sandy beaches and Sooty more often on rockier (Lauro and Nol 1995). Beach area can predict the number of Piping Plovers on wintering grounds (Ledee *et al.* 2008) and beach width is important to nesting Piping Plovers (Prindiville Gaines and Ryan 1988). The presence of adequate foraging areas for both adults and young may influence productivity (Patterson *et al*. 1991, Loegering and Fraser 1995, Fraser *et al*. 2005), and therefore may be a factor influencing the selection of nesting sites.

Once beach-nesting birds have decided on a site there are often different habitats present within that site available for nesting. Relative differences in habitat characteristics often influence nest-site selection and nest success. As a result, habitats are often used unevenly. Different patches of substrate within a site can act as different habitats.

Common Terns (*Sterna hirundo*) used patches of dry grass over other available substrates (Severinghaus 1982), presumably due to beneficial impacts on nesting success. Habitats defined using a variety of habitat characteristics (i.e., slope, vegetation type, and topography) also were found to be used unevenly by nesting Skuas (*Catharacta* spp.) and Kelp Gulls (*Larus dominicanus*) (Quintana and Travaini 2000). Longitudinal sections of the beach differ in relative threats of predation and tidal flooding. Least Terns prefer to nest in the middle of the beach as opposed to near the ocean or near the dunes in order to mediate these two threats (Burger and Gochfeld 1990).

The area directly surrounding the nest is referred to as “microhabitat” (Bergin 1992, Rodrigues 1994, Chase 2002) and the exact placement of a nest within a particular habitat depends on microhabitat characteristics. Vegetation and objects may influence nest microclimate through shading or acting as a windbreak (Walsberg 1981, With and Webb 1993, Tomkins 1944). In beach-nesting birds vegetation and objects may serve additional functions, such as concealing nests from predators, providing shelter for chicks (Burger 1987), and making nests easier to locate for parents (Page *et al.* 1985) . Nesting substrate also may influence the temperature of the nest, and ultimately affect the survival of eggs (Bergstrom 1989). Certain substrates are believed to be better suited for providing camouflage to eggs (Bergstrom 1988a, Prindiville and Gaines 1988) and young chicks (Burger 1987). It has also been proposed that areas with more shell or pebble cover indicate an area that is less frequently inundated by tides (Burger 1987). Plovers do not bring food to chicks, but instead have precocial young that are led to foraging areas (Bergstrom and Terwilliger 1987, Bergstrom 1988a), so adequate feeding areas in a distance and terrain traversable by young chicks also might be a consideration for nest-site placement within a habitat by plovers.

Nest-site selection is not always straightforward and can involve trade-offs among habitat characteristics. The positive effects of vegetation and objects on microclimate (Tomkins 1944, Walsberg 1981, With and Webb 1993) may be countered by an increase in vulnerability to predators. By blocking the line of sight of incubating plovers, vegetation and objects are thought to decrease the distance from which beach-nesting birds can spot predators (Gotmark *et al.* 1995). Placing nests near vegetation has been speculated to aid a predator's search image (Page *et al.* 1985, Burger 1987). A similar trade-off also has been proposed in regard to distance from dunes and distance to the high tide line. Nesting close to dunes may increase the chance of nest predation, but as beach-nesting birds move nests away from dunes and closer to the high tide line, the chance of losing a nest to flooding may increase (Burger 1987, Burger and Gochfeld 1990).

Nest-site selection has been studied extensively in Piping Plovers, Snowy Plovers and various species of beach-nesting Terns, but rarely in Wilson's Plovers (*Charadrius wilsonia*). Information regarding Wilson's Plovers' breeding biology has been based on studies performed in Texas, Virginia (Bergstrom 1981, 1982, 1986, 1988a, 1988b), and Georgia (Corbat 1990). Likewise, nest-site selection of Wilson's Plovers has been studied only in Texas, Virginia (Bergstrom 1982, Bergstrom 1988a), and Georgia (Corbat 1990). Range-wide information about the species is lacking. The current population size of Wilson's Plovers is uncertain, creating concern that like other obligate beach- nesting species, such as the Piping Plover and the Snowy Plover, the Wilson's Plover population is also decreasing. Wilson's Plovers are listed as threatened in South Carolina (SC DNR

2006a) and listed as a species of concern or priority in the U.S. Shorebird Conservation Plan and by organizations such as the National Audubon Society (Corbat and Bergstrom 2000, Hunter 2002, National Audubon Society 2002).

Wilson's Plovers are also seen as a special concern because they share similar nesting habits and habitats with endangered Piping and Snowy Plovers. Nesting Wilson's Plovers can be found on the beaches along the Atlantic coast of the southeastern United States, along the coast surrounding the Gulf of Mexico, the beaches of Baja California, the West Indies, and on coasts in Central and South America (Corbat and Bergstrom 2000). As do other endangered plovers, Wilson's Plovers construct a simple nest or "scrape" on bare sand or soil, often on coastal beaches, making them vulnerable to similar threats. Like other endangered beach-nesting species, loss of breeding grounds from human development and recreation (Epstein 1999) is seen a potential threat to the Wilson's plover population.

Because of the lack of information pertaining to nest-site selection in Wilson's Plovers and the conservation concerns regarding the species, I studied nest site selection of Wilson's Plovers in South Carolina. I studied nest-site selection at three spatial scales: landscape, habitat and microhabitat. At the landscape scale, Wilson's Plovers have been found nesting on barrier islands and mainland beaches along the Atlantic coast (Tomkins 1944, Corbat 1990), and on salt flats along the Gulf of Mexico coast (Bergstrom 1982, Bergstrom 1988a). However, no study has characterized these sites, or examined what characteristics predict the presence of Wilson's Plovers. At the landscape scale I examined the beaches and islands where the plovers chose to breed along the South

Carolina coast and examined the characteristics of these sites that predicted nesting Wilson's Plovers.

Within islands or beaches Wilson's Plovers nest in a variety of habitats. On the Gulf coast Wilson's Plovers nest in habitats such as sparsely-vegetated salt flats, gulf and bay beaches, roads, and airstrips (Bergstrom 1982). On Atlantic coast beaches the habitats used by nesting Wilson's Plovers include open sandy areas, the base of dunes, overwash areas, "sparsely-vegetated" predunes, behind the primary dunes, and on newly accreted sandy areas (Tomkins 1944, Corbat 1990). In my study sites I identified habitats and described the habitats used most often by the Wilson's Plover for nesting.

Various microhabitat variables have been evaluated at Wilson's Plover nests. Wilson's Plovers show variation in their nest placement with regard to objects (Tomkins 1944, Bergstrom 1988a). However, nests were often found near clumps of vegetation (Bergstrom 1988a). In some studies plovers appear to nest more often in sparse vegetation than in thick vegetation (Tomkins 1944, Bergstrom 1988a), but others show that vegetation around the nest is variable (Corbat 1990). Nests have been found on varying substrate: in Texas they were found on rock, shell, gravel, concrete and asphalt pavement (Bergstrom 1982, Bergstrom 1988a); on Atlantic beaches nests have been found mostly on sand (Corbat 1990). I examined which microhabitat characteristics were able to predict the presence of Wilson's Plover nests at my study sites.

Methods:

Nest-site selection at the landscape scale:

To study nest-site selection at the landscape scale I organized a state-wide survey of breeding Wilson's Plovers. Seventeen surveyors counted plovers at 26 sites in 2006 and 2007 (Table 1). Surveys occurred between May 1 and June 15 of each year. Surveys were done on foot or by ATV, and surveyors recorded the number of adult plovers seen along the length of beach surveyed. I assumed adults found during the surveys were breeding birds and used the numbers of adults to calculate the density of Wilson's Plovers per kilometer at each site. For sites surveyed more than once, I used the mean count of adult plovers to determine the density. Densities of Wilson's Plovers were used in analyses to examine relationships between breeding plovers and site characteristics (Table 2).

Because the characteristics of the areas surrounding the immediate surveyed area may influence Wilson's Plover abundance, I measured habitat characteristics beyond the area that was physically surveyed. To analyze these characteristics I created a buffer around the surveyed area. To do this, I imported Digital Orthographic Quarter Quadrangles (DOQQ), from the SCDNR GIS data clearinghouse (SC DNR 2006b) into ArcGIS 9.2 (ESRI, Redlands, CA). DOQQ images were from 2006. In ArcGIS 9.2 I created a layer on top of the DOQQs indicating the length of shoreline covered by the surveyor at each location, and then defined a long axis across the surveyed area that ran roughly parallel to the shoreline. By adding a 1500-m buffer on either side of the long axis (extending 1500 m inland and 1500 m towards the ocean), I created a rectangle and used the non-ocean portions of these rectangles in the landscape-level analysis (Figure 1). A 1500-m buffer was considered a reasonable buffer because breeding Snowy Plovers were found foraging up to 3.7km away from nest-sites (Paton 1995). Three sites were not used in the analysis because the surveyors did not report the length of shoreline surveyed or the coverage of the shoreline was not continuous: South Bull Island, Seabrook Island, and the Savannah River Spoils Site.

Of the remaining sites that were used in the analysis I manually manipulated the boundaries of seven because buffers of neighboring sites overlapped. Discrete sites averaged 2.9 km in length and ranged from 0.6 to 6.8 km. I merged the smallest overlapping sites (Pawleys Island and North Debidue) into one site because, when merged, the site was 2.5 km and fell within the range of the other discrete sites. Murphy's Island, Cape Island, and Lighthouse Island formed one very large site covering 20 km of shoreline so I split these sites using natural barriers, creating sites that were closer to the size range of the other sites and which represented discrete islands (Figure 2). Murphy's, Cape, and Lighthouse Islands measured 5.9 km, 4.9 km, and 9.3 km, respectively, after being split. Deveaux Bank and Botany Island also were split because, when combined, the 1500-m buffer would not have included all of the surveyed area at Botany Island and a large portion of the island would not have been included in the analysis. Sites that were split were the only sites that were not rectangular (Figure 2). Splitting sites in this way changed the area of the buffers at the affected sites by only 1-7% and was not expected to significantly impact further analysis.

After defining the buffers I examined the DOQQs using ArcGIS 9.2. At each site I manually delineated three habitat types: beach, marsh, and urban development (Figure 3). I delineated beach and marsh while viewing DOQQs at a 1:6000 scale, and urban development at a 1:10,000 scale. I defined "beach" as an area that was a potential nesting site for Wilson's Plovers: bare sand and sparsely vegetated sand (Tomkins 1944, Bergstrom1988a, Corbat 1990). These areas (as confirmed by observations made on the ground at Lighthouse and North Island) typically appeared sand colored or light gray on DOQQs.

I defined marsh to include both high marsh and low marsh, and included both salt marsh and freshwater impoundments. I also included tidal creeks less than 50 m wide. In instances where I had trouble defining the marsh using only aerial photographs, I referred to an NWI GIS layer to see if the area had been designated historically as a wetland. NWI maps were downloaded from the SC GIS data clearinghouse (SC DNR 2006b). I designated areas of urban development using a combination of DOQQs and NWI maps, as well. By setting the NWI map as partially transparent I looked at both the DOQQ and the NWI delineations. Areas that were classified as Residential, Commercial, Transportation, or Other Urban by the NWI maps were considered urban, as were areas that were not so designated on the NWI maps if human development was present on the DOQQ. NWI maps were based on 1989 and 1994 data so did not take into account more recent development.

I also estimated the distance to other sites occupied by nesting Wilson's Plovers using DOQQs analyzed in ArcGIS 9.2. I marked the two closest corners of neighboring site polygons and calculated the distance between them. For sites that shared a common boundary, I measured the distance between the two closest points of beach at the two sites.

I assessed human accessibility of the site (road access, boat access, restricted access) and ownership (private, state, federal) of each site using a combination of DOQQs, County GIS data, and personal communication with individuals who surveyed the sites and individuals at the appropriate town halls. I defined ownership as the ownership of the beach front at a particular site. Some sites consisted of beach front that had a combination of owners or a combination of accessibilities. In these cases I made the ownership and accessibility designations by using the category that made up 50 percent or more of the total area. Accessibility and ownership were treated as categorical variables.

Because the number of sites with no human development and sites with development were roughly even, a Kruskal-Wallis test was run to examine if there were differences in Wilson's plover densities between undeveloped and developed sites. Undeveloped sites were defined as sites that contained no human development, developed sites were defined as sites that contained any amount of human development.

I ran a stepwise multiple linear regression with percent beach, percent marsh and percent development to see which best predicted the density of Wilson's Plovers (per km) at a site. Using SPSS statistical software (Version 13.0) I arcsine square root transformed the data and ran a ridge regression to check the stability of significant variables. I also ran a separate linear regression with distance to closest Wilson's Plover breeding site. Accessibility, ownership, and presence of development were not included in the regression and were analyzed using Kruskal-Wallis tests in SPSS.

Nest-site selection at the habitat scale:

To study whether Wilson's Plovers favored particular habitats for placing their nests, I intensively surveyed two sites for Wilson's Plover nests: the northern portion of North Island, Georgetown County, SC (Figure 4) and Lighthouse Island, Charleston County, SC (Figure 5). North Island is a barrier island separating North Inlet and Winyah Bay from the Atlantic Ocean, and is part of the Tom Yawkey Wildlife Center

Heritage Preserve. Lighthouse Island is a barrier island in Cape Romain National Wildlife Refuge. The two sites were surveyed 1-2 times per week from April until July 2006 and from March until August 2007. At North Island nest searching focused alternately between the northern half and the southern half of the study site. At Lighthouse Island the surveyed area was split into three areas which were alternately surveyed. The western-most portion was a sandspit with restricted access due to Least Tern nests. In 2006 the sandspit was surveyed once during a Least Tern survey by a group of surveyors. In 2007 the sandspit was surveyed twice before and twice after Least Tern nesting. The two latter surveys were conducted during Least Tern and Black Skimmer surveys by a group of surveyors. At both sites I searched for Wilson's Plover nests by walking through potential breeding habitat (sandy areas that were not completely dominated by vegetation). I located nests by following Wilson's Plover tracks and by observing the behavior of adults.

I defined seven habitat categories on North and Lighthouse Islands using ArcGIS 9.2 (Table 2). I overlaid a LIDAR image on top of an aerial photograph of my study sites. I gathered GPS coordinates in the field at the boundaries of dune and overwash systems and overlaid those on the other two layers. Using these three data layers, I delineated the surveyed area at both sites. Within the entire surveyed area I used aerial photographs, elevation data (gathered from LIDAR), and ground truthing (GPS coordinates) to define habitat types based on dune density, dune structure, and frequency of overwash. I based my methods on those used by the North Carolina Geological Survey in the geographic mapping of the Cape Hatteras National Seashore (Hoffman et al. 2007).

I used a chi-square test to examine if Wilson's Plovers used habitats differently than would be expected due to chance based on the areas of the habitats. I estimated the number of nests that would be expected in the habitats based on area. Using a chi-square test I examined if the observed number of nests was significantly different than expected. Because the areas of dunes with active overwash and overwash with isolated dunes were small and the expected values of nests in these categories were less than 1, they were combined with overwash to form a single category called "combined overwash" for the chi-square analysis at Lighthouse Island.

Nest-site selection at the microhabitat scale:

North Island and Lighthouse Island were also used as study sites for the microhabitat scale question. The same method of nest searching was used for the microhabitat scale as was used in the habitat scale but only data collected in the 2007 field season was used in microhabitat scale analyses.

To assess nest microhabitats I took ten measurements at each nest (Table 2). After locating a nest, I placed a 1 m^2 quadrat of PVC piping around the nest and photographed the nest from distances of 1 and 8 m. Using the photographs I estimated the percentage of shell and plant cover surrounding the nest within the 1 m^2 quadrat by overlaying a grid on a photograph of the 1 m^2 quadrat. Each time a piece of vegetation (any portion of a rooted plant) coincided with a "crosshair" of the grid, I marked it. I counted all the marks and divided by the number of total "crosshairs" to get a percentage. I used the same method for shells (any shell larger than a dime) to estimate percent shell cover.

I measured the distances to the high tide line and the closest foraging area using a pace count, except in areas that were not traversable. In these cases I estimated the distances using a measurement tool in Google Earth Plus.

For each study site I generated random points using aerial photographs by drawing a rectangular perimeter around each habitat category. Using Google Earth I estimated the latitude and longitude of each corner of the created rectangle. I used the random numbers function in Microsoft Excel and generated random latitude and longitude coordinates that fell within the four corners of the rectangle. Each random coordinate was the location of the random point. I measured the same variables at random points that I had at nest sites. I collected data from roughly twice as many random points in each habitat type as the number of nests found.

I compared nest sites and random points using multiple logistic regression to assess which variables could predict the presence of Wilson's Plover nests. Before running the regression I assigned values to cases in which measurements were taken only within a designated distance from the nest or random point. I assigned the value 707 cm to any case that did not have a shell or dead vegetation within the 1 m^2 quadrat because it was the longest distance from the center of the quadrat to the perimeter. For distance to closest object I assigned cases that did not have an object within 5 m to be 5000 cm. I then ran a stepwise logistic regression using R. I chose the model with the lowest AIC value and then removed any non-significant variables from the model except when removal heavily affected the AIC value. I ran the logistic regression first for all of the data combined. I then divided the data and ran a logistic regression using North Island data and Lighthouse Island data independently. Finally, I divided the data again and ran a logistic regression for any habitat category that contained 9 or more nests.

Results:

Landscape Scale Analysis

Twenty-six sites were surveyed and 22 were used in analyses (Table 3). Three sites, North Island, Cedar Island, and Lighthouse Island each had 40 or more Plovers, and combined, these three sites contained over 40% of all the Wilson's Plovers counted during the 2006-2007 Wilson's Plover survey. The survey covered about 30% of the South Carolina coastline.

On average, sites contained 3.9% ± .2 (range: 1.2 - 8.0%) beach, 23.0% ± 1.3 (range: 0 - 45.5%) marsh, and 4.8% ± 8.2 (range: 0 - 25.1%) urban development. Distances between occupied nesting sites averaged 5.92 km ± 11.25 (range: 7 m - 49.8 km). Nine of the analyzed sites were privately owned, nine were state owned and four were federally owned. Seven sites had restricted access, eight were accessible by boat, and seven were accessible by road. Ten sites were developed and 12 sites were undeveloped.

One of the three characteristics included in the multiple linear regression at the landscape level was a significant predictor of Wilson's Plover density. Percent of beach ($r^2 = 0.299$, $P = 0.008$) was positively correlated with density of adult Wilson's Plovers (per km) (Figure 7). Area of marsh and area of human development were not significant and not included in the model. Distance to other nesting sites also was not significant.

Wilson's Plover density did not differ significantly based on accessibility of the site (Kruskal-Wallis, $X^2 = 2.70$, df = 2, $P = 0.260$) or ownership of the site ($X^2 = 2.98$, df

= 2, P = 0.226). Density of plovers at developed and undeveloped sites was significantly different ($X^2 = 4.60$, df = 1, P = 0.032; Figure 8). Density of plovers was higher at undeveloped sites with a mean of 7.0 ± 1.86 plovers/km than at developed sites which had a mean of 2.0 ± 1.09 plovers/km.

Habitat Scale Analysis

North Island:

2006: I recognized seven habitats on North and Lighthouse Islands. Five were found on North Island: overwash, overwash with isolated dunes, dunes with active overwash, elevated dune field, and elevated ridge and swale. Only overwash, overwash with isolated dunes, and dunes with active overwash were surveyed in 2006. I located 14 Wilson's Plover nests across the three habitats in 2006 (Figure 9). Wilson's Plovers used the habitats differently than would be expected based on the area of the habitats. Overwash with isolated dunes was overused by the Wilson's Plovers ($X^2 = 6.08$, df = 2, $P < 0.05$; Table 4).

2007: I located 38 nests across the five habitats surveyed in 2007 (Figure 10). The habitats were used differently than would be expected based on the areas of the habitats. Wilson's Plovers overused overwash with isolated dunes and dunes with active overwash ($X^2 = 28.94$, df = 4, $P < 0.01$; Table 4).

Lighthouse Island:

2006: I recognized five habitats on Lighthouse Island: Overwash, overwash with isolated dunes, dunes with active overwash, low elevation ridge and swale, and active sandspit. Four habitats were surveyed in 2006 across which 13 nests were located (Figure 11). Combining habitats left three habitats for analysis: combined overwash, low elevation ridge and swale and active sandspit. Wilson's Plovers used habitats differently than would be expected based on the areas of the habitats ($X^2 = 11.24$, df = 2, $p < 0.005$, Table 5). Active sandspit was overused.

2007: Twenty-two nests were located across five surveyed habitats (Figure 12). Combined overwash, low elevation ridge and swale, and active sandspit were used in analysis. The results of chi-square analysis indicated that Wilson's Plovers were not using the habitats differently than would be expected based on the areas of habitats ($X^2 = 1.14$, df = 4, P = 0.88).

Microhabitat Scale Analysis:

Data combined from all habitats on both Islands:

Of the 10 habitat variables measured at the microhabitat scale, five variables predicted the presence of Wilson's Plover nests (Table 6). Distance to live vegetation, distance to dead vegetation, and distance to shell all were negatively correlated with the presence of Wilson's Plover nests. Slope and percent shell cover were positively correlated with the presence of Wilson's Plover nests.

North Island Data:

At North Island five of the ten measured variables were significant predictors of Wilson's Plover nests (Table 7). Distance to live vegetation and distance to dead vegetation were negatively correlated with the presence of Wilson's Plover nests. Distance to shell, slope, and percent vegetation cover were positively correlated with the presence of nests.

Lighthouse Island data:

At Lighthouse Island three variables were significant predictors of Wilson's Plover nests (Table 7). Distance to dead vegetation was negatively correlated with presence of Wilson's Plover nests, whereas slope and percent shell cover were positively correlated with nests.

Overwash, dunes with active overwash, and active sandpsit data:

Overwash, dunes with active overwash, and active sand spit each had nine or more Wilson's Plover nests. Only overwash had variables (three of ten) that significantly predicted the presence of Wilson's Plover nests (Table 7). Distance to live vegetation was negatively correlated with presence of Wilson's Plover nests. Percent shell cover and slope were positively correlated with the presence of Wilson's Plover nests.

Discussion:

Nest-site selection appears to occur to some degree at all three spatial scales analyzed in this study. Landscape-scale nest-site selection was influenced most by area of beach and presence or absence of human development. Different habitats within sites were used unequally, potentially to mediate threats to nest success. Similarly, a number of microhabitat variables were correlated with the presence of Wilson's Plover nests.

Landscape scale:

The percent area of beach at a site was positively correlated with the density of adult Wilson's Plovers. Beach area at Plover breeding sites has not been evaluated frequently, but a wintering study of Piping Plovers showed that Piping Plover abundance was positively correlated with beach area at wintering sites (Ledee *et al.* 2008). The width of beach at nesting and wintering locations within a site has also been evaluated. Beach width was greater at nesting sites of Piping Plovers than at random points, and was greater at sites used by wintering Piping Plovers than at non-used sites (Prindville Gaines and Ryan 1988). Wider beaches may help prevent nests from being washed out by tides and might decrease the chance of predation (Prindville Gaines and Ryan 1988). Maximum beach width and percentage of beach were positively correlated at the sites in this study.

Human presence can negatively impact beach-nesting birds by interfering with foraging (Burger 1994), lowering nest success (Rusticali 1999, Ruhlen *et al.* 2003), and disturbing incubating adults (Weston and Elgar 2007). Few studies have evaluated the impact of human development on nest-site selection. A wintering study found fewer Piping Plovers in areas that had greater human development (Ledee *et al.* 2008). My study did not show a correlation between percent area of human development and density of nesting Wilson's Plovers. However, the density of Wilson's Plovers was significantly greater at undeveloped sites than at developed sites. Similarly, Eurasian Oystercatchers avoid nesting in areas with human development (Rusticali *et al.* 1999).

Human presence on beaches can lower hatching success and chick survival, interfere with brood foraging, and flush incubating adults from nests (Flemming *et al.* 1988, Burger 1994, Rusticali 1999, Ruhlen *et al.* 2003, Weston and Elgar 2007). In my study, however, accessibility of breeding sites to humans was not significantly correlated with Wilson's Plover density. While human presence may influence nest success, it may not influence nest-site selection. Wilson's Plovers return to breeding grounds in March (Tomkins 1944, personal observation). Site selection may not have been influenced because Wilson's Plovers may have already chosen nesting sites before people use beaches more heavily for recreation later in the summer.

Wilson's Plovers did not appear to be limited by the amount of marsh at the sites, which was unlike a study of wintering Piping Plovers in the gulf coast (Ledee *et al.* 2008). However, prey items taken by the two species differ as Wilson's Plovers feed heavily on fiddler crabs on their breeding (Bergstrom 1982) and wintering grounds (Thibault and McNeil 1994, Thibault and McNeil 1995). Wilson's Plovers also forage with chicks in low, wet areas among vegetation, at shallow ponds, and on mud flats (Bergstrom and Terwilliger 1987, Bergstrom 1988a), so they may not depend on marshes for foraging as much as wintering Piping Plovers.

Habitat scale:

On North Island in both years Wilson's Plovers used some habitat over others. In 2006, the birds over-used overwash with isolated dunes. In 2007, the birds over-used overwash with isolated dunes as well as dunes with active overwash. Beach-nesting birds are vulnerable to predation and wash-outs (Page *et al.* 1985, Haig and Oring 1985, Patterson *et al.* 1991), and may have to balance the two threats (Burger and Lesser 1980, Burger and Gochfield 1990). By nesting closer to dunes, beach-nesting birds may escape flooding, but may be more susceptible to predators (Burger and Lesser 1980, Burger 1987). Dunes also afford predators a place to live (Burger and Gochfeld 1990). Presumably, in open areas beach-nesting birds can see predators approaching, but are prone to flooding (Burger and Lesser 1980, Burger 1987). The two areas that were over-used on North Island may be the best area to balance these two threats as they combined both dunes and overwash.

Nest patterns and differences in habitat use may be attributed to factors other than dune and overwash structure. For example, overwash with isolated dunes and dunes with active overwash were next to potential feeding areas, which might have influenced nest placement. Additionally, Wilson's Plovers can show a form of group defense (Corbat and Bergstrom 2000, personal observations), in which neighboring pairs will cross territory boundaries to lead away a potential predator. Therefore, there also may be some sort of social influence in nest placement.

On Lighthouse Island Wilson's Plovers showed differing patterns in the two years of study. In 2006, Wilson's Plovers over-used active sandspit habitat. Like the habitats that were over-used on North Island, active sandspit was a mixture of small dunes and overwash. This area also was next to a mud flat on which Wilson's Plovers were seen foraging (personal observation). In addition, the sandspit was a nesting area for Least Terns and Black Skimmers. Piping Plovers and Snowy Plovers can nest in association with terns and benefit from their association (Burger 1987, Powell 2001). Both species are more productive when nesting among terns, presumably from the added defense and vigilance of the terns (Burger 1987, Powell 2001). Wilson's Plovers might also benefit by nesting within a Least Tern colony.

In 2007 at Lighthouse Island, Wilson's Plovers did not use the habitats differently than would be expected due to the areas of the habitats. The pattern of habitat use may have differed between North Island and Lighthouse Island because the habitats themselves differed between the two islands. On North Island, overwash with isolated dunes and dunes with active overwash comprised 7.3% and 11.9%, respectively, of the entire surveyed area and were over-used by Wilson's plovers. On Lighthouse Island, these habitats only comprised 0.9% and 3.1%, respectively, of the entire surveyed area. Additionally, the underused habitats on North Island, elevated dune field and elevated ridge and swale, which accounted for 7.9% and 15.5% of the entire surveyed area, were not present on Lighthouse Island. The remaining habitats may have not varied enough in protection from predation or wash-outs to be used differently. Additionally, on North Island, the over-used habitats were next to potential foraging areas, while two of the underused habitats were not. On Lighthouse Island, all of the habitats were next to potential foraging areas. If access to foraging areas is a driving factor in habitat selection, this difference might explain why habitats on Lighthouse Island were not used more than would be expected based on area.

Differences in use of habitats between years may be attributable to differences in the surveyed areas from year to year. In 2007, the survey area was extended to include an area of overwash and an area of dunes with active overwash that were not surveyed in 2006. This area contained several nests within the overwash habitat. The dynamic nature of barrier islands may also lead to differences in the habitats from year to year. Finally, differences in weather between the two years also might have caused differences in habitat selection. The total precipitation from March 1- July 31 in 2006 was 53 cm at a nearby weather station in Charleston, SC while in 2007 it was only 33 cm (Weather Underground 2008).

Habitats were defined so that they would be applicable to a wide variety of islands delineated easily using remote tools. However, these habitats could have been divided further, such that smaller differences between habitats may have been detected which were relevant to breeding Wilson's Plovers. For example, slight elevation differences seemed to coincide with the location of nests in overwash at Lighthouse Island as the areas that appear higher and less prone to frequent tidal flooding contained more nests (personal observation).

Microhabitat scale:

Microhabitat variables were analyzed first by pooling all the data and then dividing the data into different subsets: North Island, Lighthouse Island, overwash, dunes with active overwash, and active sandspit. Each subset was analyzed independently and significant predictors were found in all tests except those run for dunes with active overwash and active sandspit. Slope was significant in all of the datasets that were found to have significant results. In all cases slope was greater at nests than at random points (Table 8). Least Terns nested on ridges and slopes and avoided nesting in troughs, potentially to gain visibility and to avoid flooding (Burger and Gochfield 1990). Nesting on slopes might give Wilson's Plovers a similar advantage. Flooding from storms can be a problem for beach-nesting birds (Haig and Oring 1985). In Wilson's Plovers loss was found after rain storms (Bergstrom 1988a) and nesting on a slope might prevent water from pooling around the nest.

Distance to dead vegetation was a significant predictor of Wilson's Plovers in all but one of the datasets. Nests were found to be closer to dead vegetation than were the random points for all of the data combined and at North Island and Lighthouse Island independently. In other studies, Wilson's Plovers put their nests close to objects (Tomkins 1944). Objects are presumed to positively influence nest environments by shading and acting as a windbreak (Tomkins 1944). Vegetative debris near the nest might have similar influences. Additionally, Mountain Plovers place nests near cow manure piles (Graul 1975). Cow manure might act as disruptive coloration or as a visual indicator to the nesting parents, so that it is easier to locate the nest (Graul 1975, Page *et al.* 1985). Dead vegetation around Wilson's Plover nests might act similarly.

Distance to live vegetation also was significant in three tests, with nests being closer to live vegetation. Additionally, on North Island the percent vegetation cover was greater at nests than at random points. Plovers placed their nests close to plants in other studies as well (Tomkins 1944, Bergstrom 1982). One study found that plants around Wilson's Plover nests were non-random and coincided with the direction of prevailing winds and sun, suggesting that a single plant or clump of vegetation might act as a source of shade or a windbreak (Bergstrom 1982). Although percent vegetation cover was slightly higher at nests on North Island than random points, the average vegetation cover at nests was only 12.9 ±1.9%. This is consistent with other findings that plovers like to nest in open areas (Nguyen *et al.* 2003), but still place their nests close to plants (Tomkins 1944, Bergstrom 1982).

Percent shell cover was a significant predictor of the presence of Wilson's Plover nests in all datasets except for North Island. Likewise, nests were significantly closer to shells at nests than at random points for all the data, but significantly further from shells at North Island. Similarly, Least Tern nests are found in areas with higher shell cover (Burger 1987). Studies of Piping Plovers have also shown that nesting sites have more pebble cover than random sites (Nguyen *et al.* 2003, Flemming *et al.* 1992). The tendency of beach-nesting birds to nest in areas with shell or pebble has been attributed to better camouflage and lower susceptibility to predation (Burger 1987, Bergstrom 1988a, Flemming *et al.* 1992, Nguyen *et al.* 2003). Shell cover also may be an indicator of areas that are not frequently washed over (Burger 1987).

The relative importance of vegetation and shell cover varied between North Island and Lighthouse Island. The differences might be attributable to differing physical characteristics of the two islands. Available substrate and amount of vegetation might vary between the two sites, which might influence nest-site selection. Relative amounts and types of predators might also differ from island to island, making nest-site selection very site specific. Mammalian predators tend to be scent driven while avian predators tend to use sight to search for prey (Picozzi 1975, Liebezeit and George 2002). Strategies for hiding nests might differ by predator.

Management Implications and Future Research:

Future research regarding Wilson's Plover's should establish a reliable population estimate, and involve continued monitoring to assess whether or not the population is stable. The breeding Wilson's Plover survey in this study did not cover a majority of the coast and was based on mostly one-time surveys. However, this study was the first attempt to establish the number of breeding Wilson's Plovers in South Carolina. Twenty-six sites were surveyed and 369 adult Wilson's plovers were counted (Appendix A), producing the first state estimate. The survey also helped to pinpoint important sites such as North Island, Cedar Island, and Lighthouse Island, which contained a large proportion of Wilson's Plovers. Future research should incorporate a survey that includes more of the coast and repeat surveys to assess the amount of variation among surveys performed on different days.

Determining what beaches and what types of beaches Wilson's Plovers nest on can aid in surveying efforts. In establishing population estimates, information about Wilson's Plover nesting habits and preferences may aid surveyors in more efficiently choosing sites to survey rather than wasting time and effort on areas that most likely will not support Wilson's Plovers. As time, money, and manpower are often limited, having the most efficient surveying procedures may aid in determining if Wilson's Plovers are threatened, and if the species should be federally listed.

Studying nest characteristics of Wilson's Plovers in geographic areas where no studies have occurred also will help establish widespread patterns of nest-site characteristics or may indicate geographic variation in nest-site characteristics. Locating geographic variation may reveal unique selection pressures of different populations of nesting Plovers (Flemming *et al*. 1992). If Wilson's Plovers are declining, it will be important to recognize and understand varying pressures in order to manage the population successfully

Establishing what beaches, islands and habitats Wilson's Plovers are nesting on can aid in management decisions about beach closures or the use of fencing to protect nesting birds as is done to protect endangered Piping Plovers. By determining the types of sites and habitats within sites that are most often used by breeding Wilson's Plovers, it may be possible to make better decisions regarding beach closures and placement of fencing to protect nesting Wilson's Plovers.

Because nest-site selection in Wilson's Plovers can aid in its conservation, it is important that research pertaining to this species is continued, particularly at the landscape and habitat scales of nest-site selection. Incorporating other factors in the definition of habitats, such as accessibility to foraging areas, also may be an important step in understanding the importance of habitat on nesting Plovers. Similarly, continuing microhabitat selection studies in this species will help indicate if there are wide-scale patterns in nest-site selection or if the importance of different habitat characteristics is site-specific. Finally, it is important that not only nest-site selection studies are carried out, but in an effort to conserve the species and understand population trends it is important that nest and fledging success are studied in relation to these habitat characteristics.

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Table 1. Sites surveyed for breeding Wilson's Plovers in 2006 and 2007 along with the county, coordinates, length of surveyed beach for each site, and the percentage of shoreline surveyed at each beach or barrier island.

Site	County	Lat/Long (N,W)	Length Surveyed (Km)	% of Site Surveyed
Waites Island	Horry	33.847, 79.577	5.9	100%
Myrtle Beach State Park	Horry	33.648, 78.929	1.8	100%
Garden City Beach	Georgetown	33.535, 79.028	1.7	71%
Huntington Beach State Park	Georgetown	33.518, 79.045	4.3	68%
Litchfield Beach	Georgetown	33.456, 79.104	3.9	52%
Pawleys Island	Georgetown	33.399, 79.140	0.4	8%
Debidue Beach – North End	Georgetown	33.387, 79.145	2.0	24%
Debidue Beach – South End	Georgetown	33.339, 79.158	4.2	48%
North Island	Georgetown	33.314, 79.162	3.4	23%
South Island	Georgetown	33.144, 79.229	3.9	32%
Cedar Island	Georgetown	33.123, 79.248	4.6	100%
Murphy's Island	Charleston	33.100, 79.316	6.2	69%
Cape Island	Charleston	33.044, 79.346	10.0	74%
Lighthouse Island	Charleston	33.008, 79.396	7.5	100%
nBull Island – North End	Charleston	32.923, 79.396	4.4	35%
Bull Island – South End	Charleston	32. 876, 79.648	Not Reported.	Not Reported
Marsh Island	Charleston	32.989, 79.549	1.0	100%
Dewees Island	Charleston	32.835, 79.707	4.7	100%
Rat Island (North Folly)	Charleston	32.692, 79. 894	1.4	12%
Seabrook	Charleston	32.561, 80.165	Not Reported.	Not Reported
Deveaux Bank	Charleston	32.542, 80.176	5.0	100%
Botany Island	Charleston	32.554, 80.210	8.0	74%
Edisto Beach State Park	Charleston	32.513, 80.284	1.7	65%
Town of Edisto Beach	Colleton	32.478, 80.335	7.1	100%

Hunting Island State Park	Beaufort	32.361 , 80.443	7.6	100%
Savannah River Spoils Site	Jasper	32.105, 81.014	Not Continuous	Not Applicable

Table 2. The names and descriptions of all habitats and habitat variables that were defined or measured for the landscape, habitat and microhabitat scales are listed.

Habitat Variable/ Habitat Type	Description
Landscape Scale	
Percent beach	Percent area of beach within 1500 m buffer.
Percent marsh	Percent area of marsh (high and low) within 1500 m buffer.
Percent human development	Percent area of human development within 1500 m buffer.
Presence of human development	Presence or absence of any human development; developed (human development present), undeveloped (no human development).
Accessibility	Human accessibility to the site: road, boat, restricted.
Ownership	Ownership of the beachfront at the site: private, state, federal.
Distance to nearest breeding site	Distance between the two closest corners of adjacent site buffers.
Habitat Scale	
Overwash	Low and flat area of sand that has few dunes.
Overwash with isolated dunes	An area with more overwash than dunes. Dunes are recently formed and isolated or isolated due to washover.
Dunes with active overwash	An area that is predominantly dunes but has areas of active overwash between the dunes.
Elevated dunefield	An elevated system of dunes that does not have active overwash
Elevated ridge and swale	An elevated system of dunes that has a parallel organization of dunes and troughs.
Low elevation ridge and swale	A system of dunes that has a parallel organization of dunes and troughs, but the troughs are often washed over.
Active sandspit	Area of sand extending into the water and surrounded on three sides by water.
Microhabitat Scale	
Live vegetation	Distance to nearest plant matter that was still rooted.
Dead vegetation	Distance to nearest plant matter longer than 15 cm and no longer attached to a rooted plant within the 1 m^2 quadrat
Shell	Distance to nearest object larger than a tennis ball within a 5 m radius of the nest or random point.
Object	Distance to nearest shell larger than a dime within the 1 m^2 quadrat.

Dune	Distance to nearest dune that was at least 2 m^3 in volume.
Foraging area	Distance to nearest marsh, mudflat, or tidal creek.
Wrack line	Distance to the most recent high tide mark.
Slope	Slope of the substrate extending 1m from the nest or random point.
Percent vegetation cover	Percentage of live vegetation cover within the 1 m^2 quadrat.
Percent shell cover	Percentage of shell cover within the 1 m^2 quadrat.

Table 3. The number and density of adult Wilson's Plovers counted at each site included in analyses. For sites surveyed more than once the value represents a mean.

Site	Year(s) Surveyed	# of Surveys	Mean Count (SE)	Plovers/Km
Botany Island	2006	1	6	1
Bull Island – North End	2007	1	13	4
Cape Island	2007	1	20	2
Cedar Island	2007	1	40	12
Debidue Island - South End	2007	3	2 (1)	1
Deveaux Bank	2007	1	25	14
Dewees Island	2007	1	22	6
Edisto Beach State Park	2006, 2007	2	16 (8)	11
Garden City	2007	1	1	1
Hunting Island State Park	2006	1	5	1
Huntington Beach State Park	2007	1	6	2
Lighthouse Island	2007	1	45	9
Litchfield	2007	3	3 (.67)	1
Marsh Island	2007	1	0	0
Murphy's Island	2007	1	16	3
Myrtle Beach State Park	2007	1	0	0
North Island – North End	2007	2	50 (7.5)	22
Pawleys - North Debidue	2007	1	2	1
Rat Island (North Folly)	2006,2007	3	8 (3)	6
South Island	2007	2	15 (.5)	5
Town of Edisto	2006	1	1	1
Waites Island	2007	2	8 (0)	2

Table 4. The observed and expected numbers of Wilson's Plovers nests located in the five habitats defined at North Island in 2006 ($X^2 = 6.08$, df = 2, $P < 0.05$) and 2007 ($X^2 = 28.94$, df = 4, $P < 0.01$).

	2006		2007	
Habitat Category	Observed	Expected	Observed	Expected
Elevated Ridge and Swale*			2	5.89
Elevated Dune Field*			1	3.00
Dunes with Active Overwash	1	2.17	9	4.52
Overwash with Isolated Dunes	4	1.36	11	2.81
Overwash	9	10.47	15	21.77

* Habitat categories were surveyed in 2007 only.

Table 5. The observed and expected numbers of Wilson's Plover nests found in each habitat type in 2006 at Lighthouse Island ($X^2 = 11.24$, df = 2, $P < 0.005$).

Habitat Category	Observed	Expected
Active Sandspit	10	4.33
Low Elevation Ridge and Swale	1	4.23
Combined Overwash	2	4.45

Table 6. Significant predictors of Wilson's Plover nests at the microhabitat scale established by multiple logistic regressions analyzing data from both sites and all habitats combined. The number of nests is represented.

All sites, all habitats (n = 59)				
Variable	Estimate	SE	Z-Statistic	P-Value
Live vegetation	-0.0033	0.0014	-2.447	0.0144
Dead vegetation	-0.0024	0.0007	-3.289	0.0010
Shell	-0.0016	0.0008	-2.162	0.0306
Slope	0.1972	0.0509	3.871	0.0001
Percent shell cover	0.1472	0.0358	4.112	0

Table 7. Significant predictors of Wilson's Plover nests at the microhabitat scale established by multiple logistic regressions for data divided by study site and by habitat type. The variables live veg, dead veg, per veg and per shell are abbreviations for live vegetation, dead vegetation, percent vegetation cover and percent shell cover, respectively. The number of nests for each dataset is represented.

	NI Data (n= 37)				LI Data (n = 22)				Overwash (n = 20)			
	Estimate	SE	Z-Value	P-Value	Estimate	SE	Z -Value	P-Value	Estimate	SE	Z-Value	P-Value
Live veg	-0.0082	0.0034	-2.382	0.0172	--	--	--	--	-0.0134	0.0059	-2.284	0.0223
Dead veg	-0.0023	0.0009	-2.440	0.0147	-0.0036	0.0015	-2.337	0.0195	--	--	--	--
Shell	-0.0021	0.0009	-2.374	0.0176	--	--	--	--	--	--	--	--
Slope	0.2042	0.068	3.005	0.0027	0.3408	0.1083	3.147	0.0017	0.2531	0.1109	2.282	0.0225
Per veg	-0.053	0.021	-2.525	0.0116	--	--	--	--	--	--	--	--
Per shell	--	--	--	--	0.2741	0.0661	4.145	0	0.376	0.1301	2.891	0.0038

Table 8. Means and standard errors for microhabitat variables that were significant predictors of Wilson's Plover nests. Data are shown for both nests and random points.

	All Data Mean (SE)		NI Data Mean (SE)		LI Data Mean (SE)		Overwash Data Mean (SE)	
	Nests n= 59	Random Points n= 151	Nests n= 37	Random Points n= 95	Nests n= 22	Random Points n= 56	Nests n= 20	Random Points n= 68
Slope (degrees)	6.5 (.6)	4.0 (.4)	7.6 (.7)	4.4 (.5)	4.7 (.7)	3.4 (.5)	6.6 (.9)	2.6 (.3)
Dead veg (cm)	132.5 (34.2)	321.5 (27.7)	86.1 (36.1)	333.0 (35.3)	210.4 (66.5)	302.0 (45.0)	--	--
Live veg (cm)	76.7 (20.1)	442.2 (76.4)	31.2 (12.3)	447.3 (89.1)	--	--	53.6 (21.2)	646.6 (114.5)
Shell (cm)	282.0 (44.6)	332.4 (28.1)	389.2 (57.5)	359.6 (35.5)	--	--	--	--
Percent Shell	7.2 (1.3)	2.0 (.4)	--	--	16.0 (2.5)	3.2 (.7)	3.5 (1.3)	1.4 (.4)
Percent Vegetation	--	--	12.9 (1.9)	11.0 (1.8)	--	--	--	--

Figure 1. Rectangle created at Litchfield using surveyed shoreline, long axis and 1500 m buffer.

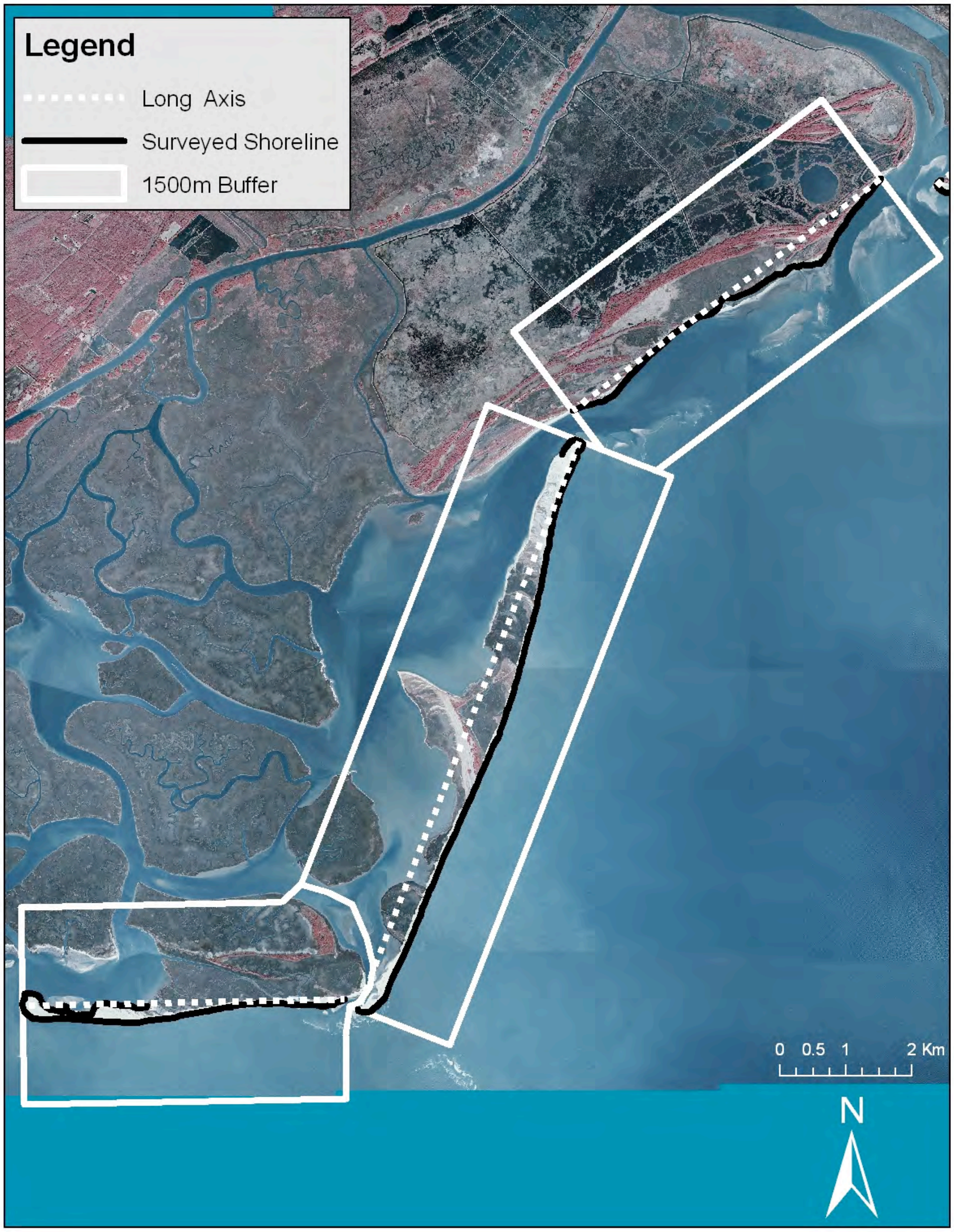

Figure 2. An image of Northern Cape Romain National Wildlife Refuge showing three islands with overlapping buffers that were split along natural boundaries.

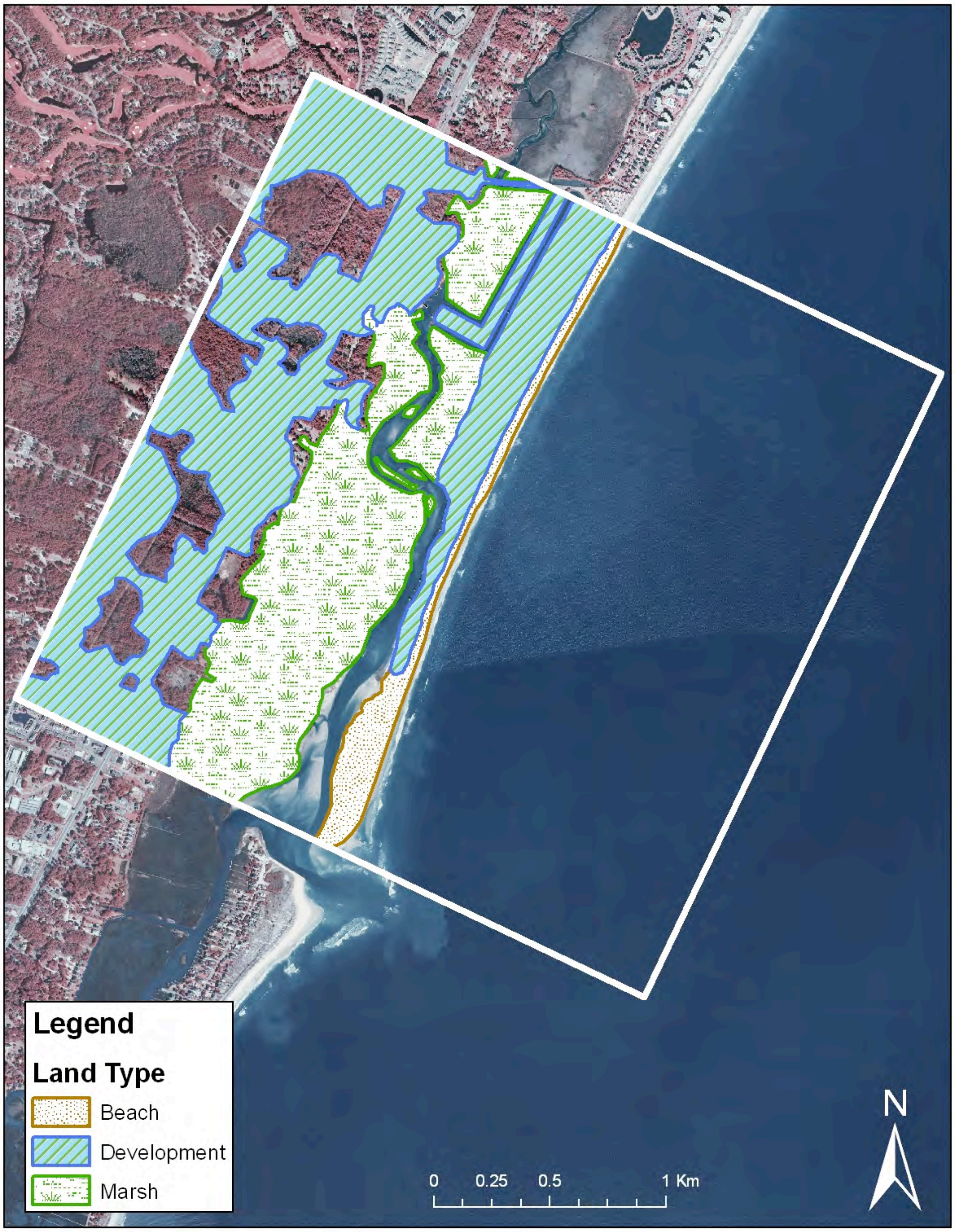

Figure 3. An example of polygons created delineating beach, human development and marsh at Litchfield.

Figure 4. The aerial photograph represents the surveyed portion of North Island. Inset shows the location of North Island relative to the South Carolina coastline.

Figure 5. Aerial photograph of Lighthouse Island with inset of the state with the location of Lighthouse Island relative to the South Carolina coastline indicated.

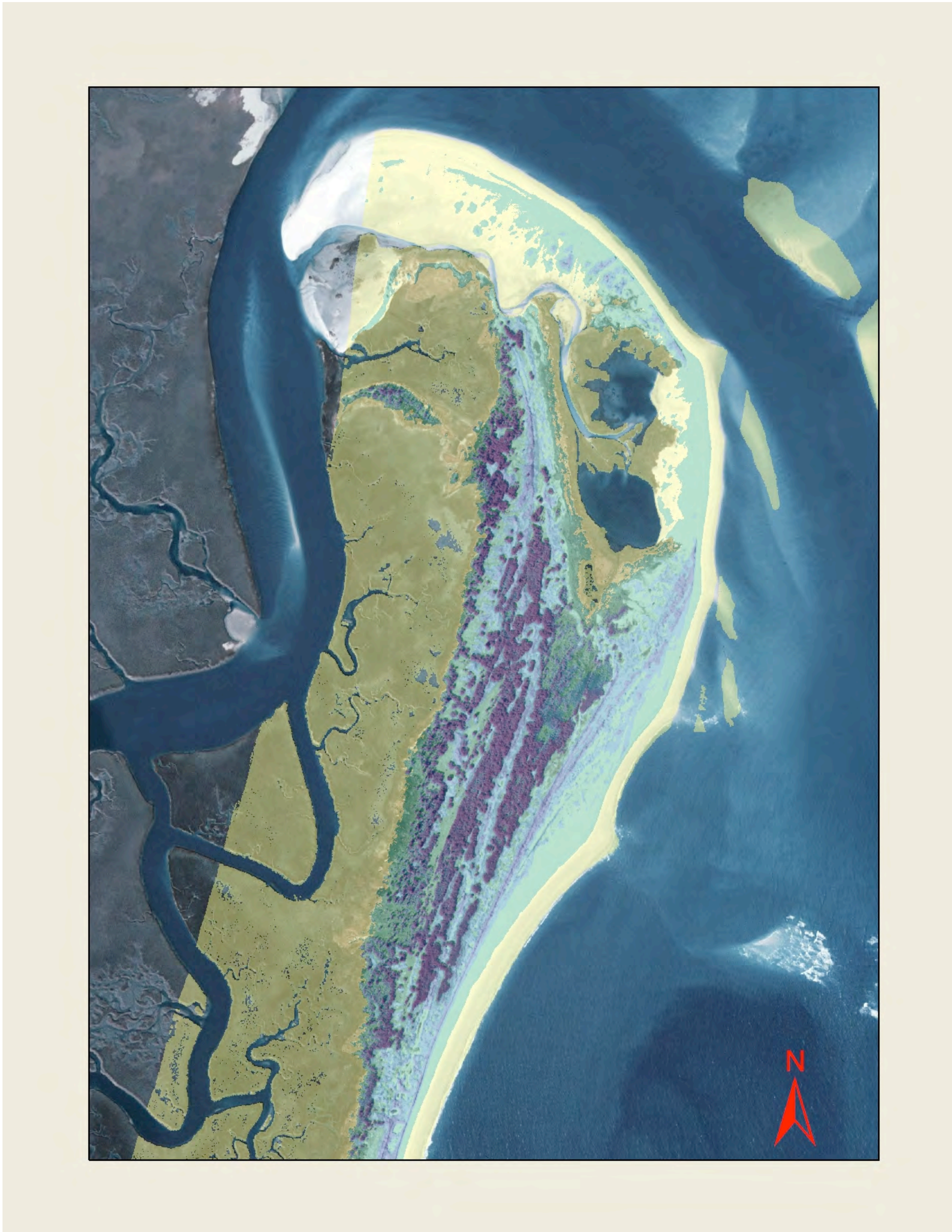

Figure 6. An image of LIDAR overlaid on an aerial photograph of North Island.

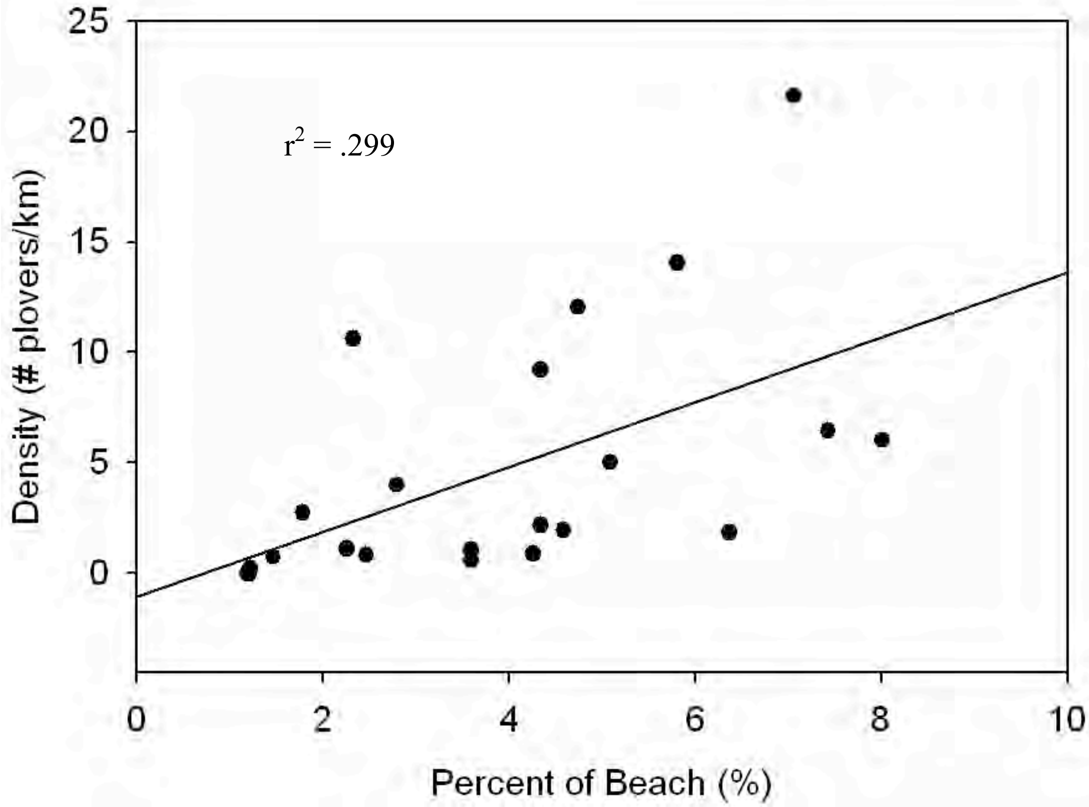

Figure 7. Breeding Wilson's Plover density is positively correlated with percentage of beach across 22 sites in South Carolina.

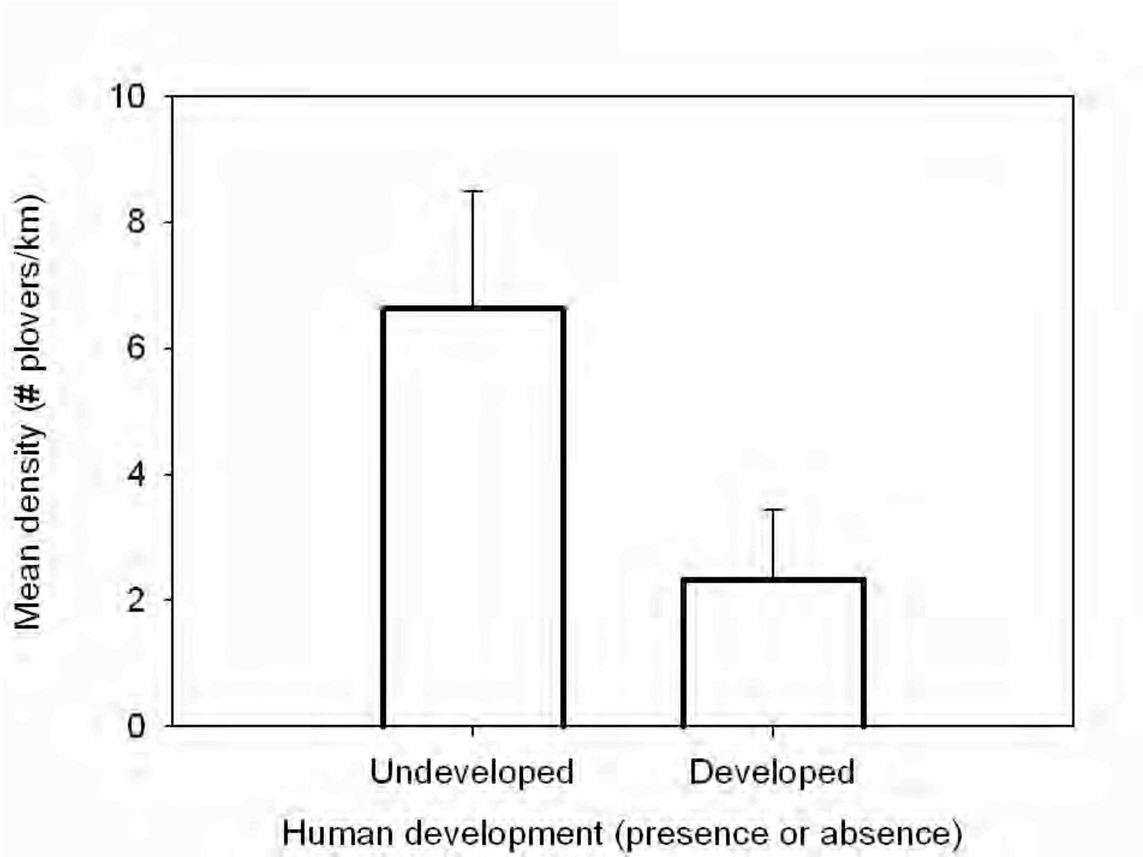

Figure 8. Mean (± SE) density of breeding Wilson's Plovers is significantly greater at undeveloped than developed sites.

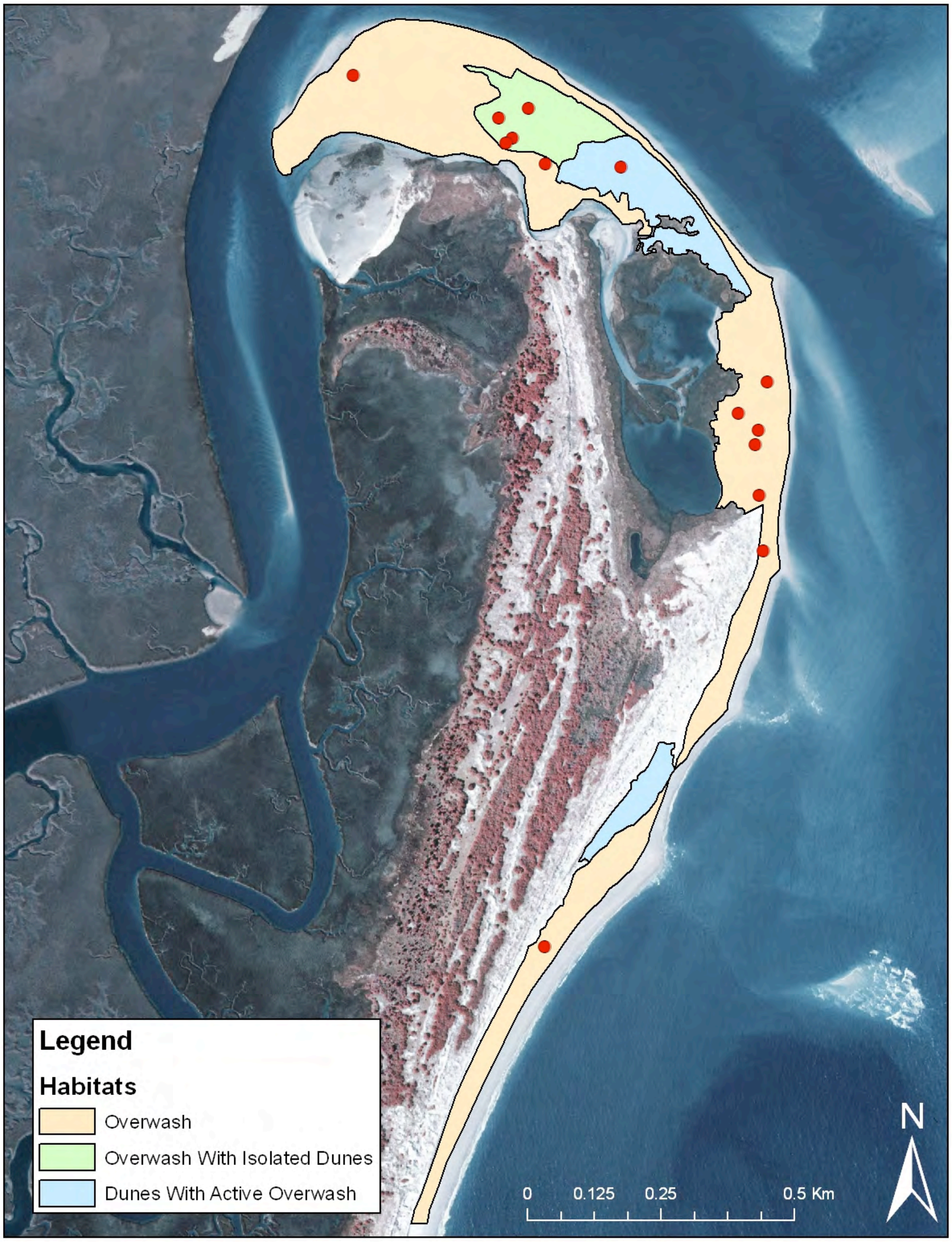

Figure 9. Nest distribution across three surveyed habitats at North Island in 2006 (n=14).

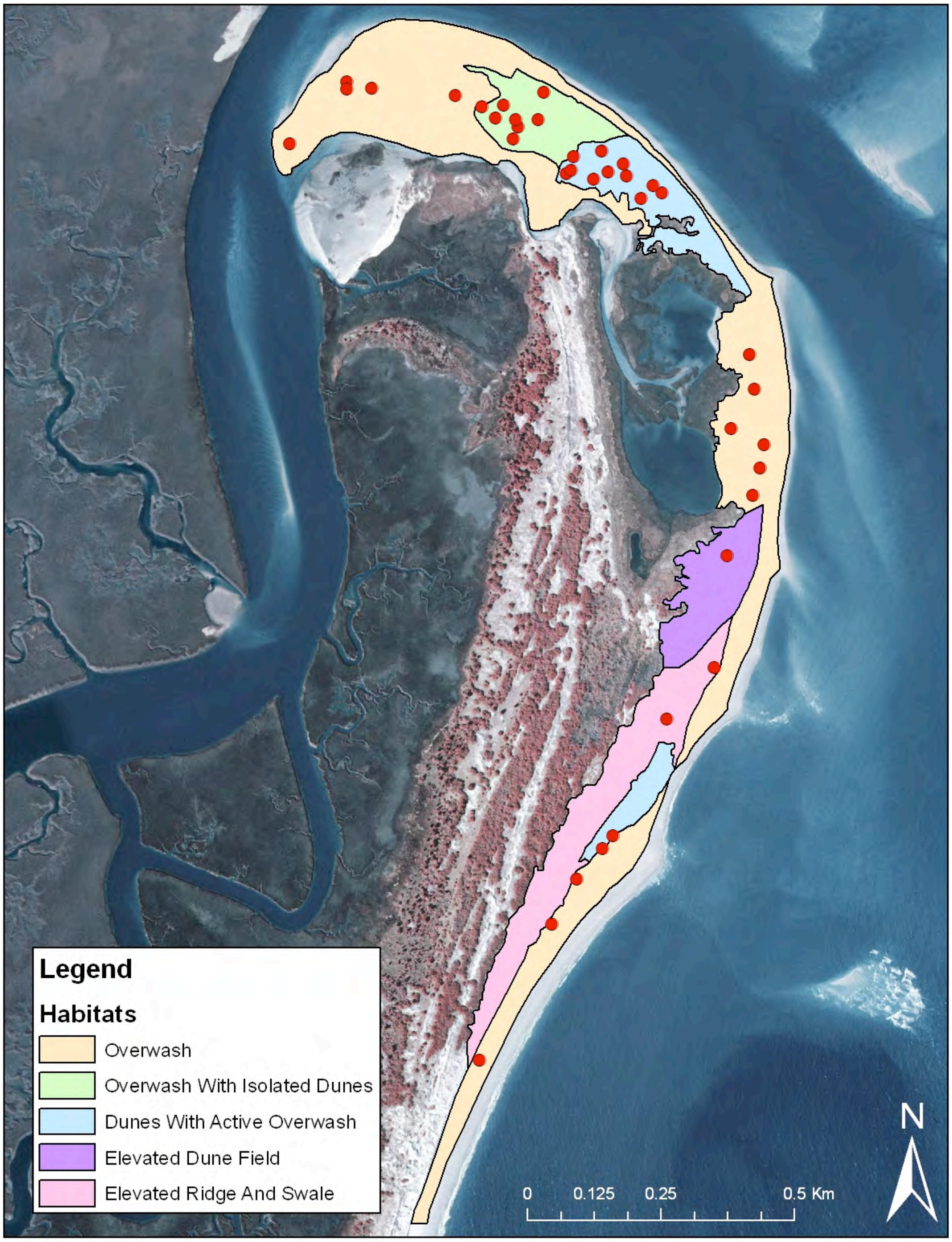

Figure 10. Nest distribution across five surveyed habitats at North Island in 2007 (n=38).

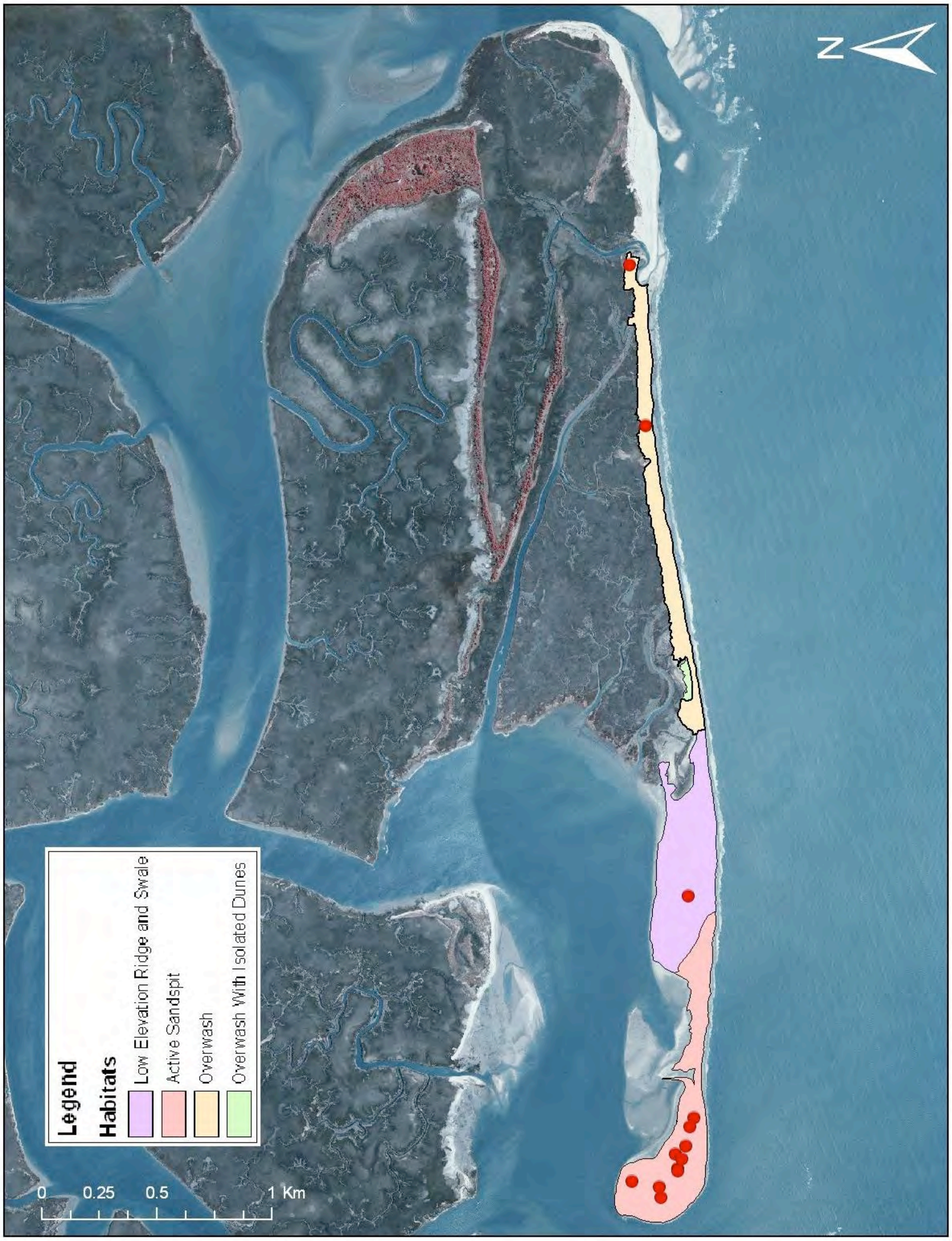

Figure 11. Nest distribution across four surveyed habitats at Lighthouse Island in 2006. Twelve of thirteen nests are pictured here.

Figure 12. The distribution of Wilson's Plover nests across five surveyed habitats at Lighthouse Island in 2007 (n=22).

Appendix A. Maximum counts of adult Wilson's Plovers at 26 sites during the 2006-2007 South Carolina breeding Wilson's Plover survey.

Site	Max Count
Waites Island	8
Myrtle Beach State Park	0
Garden City Beach	1
Huntington Beach State Park	6
Litchfield Beach	4
Pawleys Island	0
Debidue – North End	2
Debidue – South End	4
North Island (North End)	57
South Island	15
Cedar Island	40
Murphy's Island	16
Cape Island	20
Lighthouse Island	45
Bull Island – North End	13
Bull Island – South End	1
Marsh Island	0
Dewees Island	22
Rat Island (North Folly)	13
Seabrook	11
Deveaux Bank	25
Botany Island	6
Edisto Beach State Park	24
Town of Edisto	2
Hunting Island State Park	5

Savannah River Spoils	29
Total	**369**